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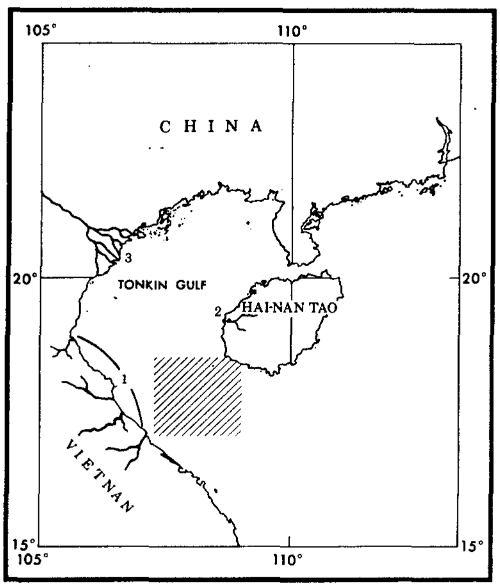
 IR NO. 69-32

INFORMAL REPORT

BOTTOM SEDIMENTS OF THE SOUTHERN GULF OF TONKIN



APRIL 1969

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NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D. C. 20390

INFORMAL REPORT

ABSTRACT

The Gulf of Tonkin is a shallow, crescent-shaped, subtropical basin. It is bordered by the continent of Asia on the north and west and the island of Hai Nan Tao on the east. The land is characterized by narrow plains and nearby highlands.

The southern Gulf of Tonkin is a NW-SE trending shallow embayment from 50 to 100 meters in depth. The deeper part is filled with poorly sorted sands and silts and is generally flanked by clays and silts. Two major deltas, the Hong and Ch'ang Chiang Ho, to the north and east and a number of minor deltas to the west supply sediments to the sea. Sediment distribution is complex and is strongly influenced by current changes due to seasonal monsoons and varying sources of clastics.

Cohesion of surface sediments increases from the shallow flanks into the deeper sandy trough. It also increases with depth on the flanks but apparently decreases in the basin. This is due to the silts and clays underlying the sands in the trough.

The NW-SE trend of the southern gulf with its sand fill results in higher wet unit weights and lower porosities along the axis.

Two older beds were recognized in some of the cores. One is a light blue, stiff clay that may be Pleistocene in age. The other bed is a reddish-brown, silty, stiff clay of Pleistocene (?) age. None of the cores penetrated both of the older beds.

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B. C. Byrnes

B. C. BYRNES
Director, Developmental
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INTRODUCTION

The Gulf of Tonkin is a crescent-shaped, shallow, subtropical basin bordered by the continent of Asia on the north and west and the island of Hai-Nan Tao on the east. All gulf sediments are derived from one or both of these land masses. Drainage from these areas carries large quantities of sediment into the gulf where they are deposited under the influence of strong water currents.

The gulf is partly bordered by highlands. The Annam Cordillera parallels the gulf on the west and southwest, and rises from 3000 to 8000 feet above sea level within 50 miles of the coast. The Sip Song Chau Thai, Fan Si Pan, and Nui Con Voi highlands form the Hong (Red) River watershed to the northwest in the Tonkin province. The minor highlands of Shihwanta Shan and Liuwanta Shan border the coast on the north in China. On Hai-Nan Tao the Limu Ling and Wuchih Shan ranges rise 4000 to 6000 feet.

All of these highlands supply a variety of clastics derived from igneous, metamorphic, and sedimentary rocks. The high rainfall and subtropical climate of the area cause a mixture of laterites and unweathered clastics.

Recent studies of Vietnam deltas (Bell, 1966; Inman and Harris, 1966) show the strong influence of weather on sedimentation. From November to March the surface currents are driven to the southeast by the winter monsoon. Between May and October the summer monsoon reverses these currents. Floods accompanying the two monsoons carry large quantities of clastics to the deltas. Strong longshore currents erode the deltas and beaches and move the sediments along the coast until they are deposited in deeper water.

The southern portion of the Gulf of Tonkin trends NW-SE and varies from 50 to 100 meters in depth. The area surveyed is bounded by latitudes 17° and 19° North and longitudes 107° and 109° East, extending northeast from the Vietnam Demilitarized Zone to the island of Hai-Nan Tao (Figure 1).

METHODS AND LABORATORY PROCEDURES

Sample Collection

From August to October 1966, units of the U. S. Navy collected 26 Phleger cores from the southeast portion of the Gulf of Tonkin. Cores were taken as operations permitted, resulting in random sample spacing. In November 1966, 53 Phleger cores and 19 Shipek grab samples were obtained by Dr. Robert Gaal (TRW Systems, Redondo Beach, California) under contract to the U. S. Navy. Additional sample locations chosen at that time completed a grid extending across the axis of the NW-SE trending basin (Figure 2).

The initial coring was accomplished by Navy personnel using a Phleger corer without liners. These cores were extruded and wrapped in numerous layers of plastic. Later cores were taken in liners and wrapped in plastic. Grab samples were sealed in doubled heavy plastic bags. All samples and cores were shipped to the Pacific Support Group, Naval Oceanographic Office, San Diego, California, for analysis.

Size Analyses

Samples were examined and described as to color, texture, mineral content, and structure. Most of the cores were subsampled at 10-cm. intervals, very short cores at top and bottom only.

Size analyses were performed on all subsamples following standard laboratory procedures (Krumbein and Pettijohn, 1938). Coarse fractions were separated with Wentworth sieves and finer fractions were determined using pipette methods. The cumulative percentages of each size fraction were plotted to determine the median diameter and quartiles. Sediment types recorded were based on Shepard's triangular diagram (Shepard, 1954). Sorting coefficient and skewness were calculated from the quartiles using Trask's formulas (Trask, 1932).

Calcium Carbonate

Calcium carbonate was determined for all subsamples as a percentage of weight loss after leaching with dilute HCl.

Engineering Properties

A laboratory vane shear apparatus (Richards, 1961) was used to determine shear strength. In finer grained sediments the angle of internal friction between grains is negligible, and shear strength is equal to cohesion. All shear strengths are reported as cohesion values (gm./sq. cm.). After testing, the samples were remolded and the disturbed strengths measured. The ratio between "initial" and "remolded" strength is the sensitivity.

Wet unit weight was determined by inserting a tube of known volume into the core, extracting the tube and sample and weighing it. The weight divided by the volume is the wet unit weight expressed in gm./cu.cm.

Each sample was weighed wet and dry. The water loss was used to calculate the moisture content. Moisture content is defined as the percentage of the weight of water loss divided by the dry weight of the sample. This should not be confused with water content, which is expressed as a percentage of the total (wet) weight.

Porosity was calculated by dividing the weight of the contained water by the volume of the sample; i.e., porosity equals the water content (expressed as a percentage of unit volume). This is true only if the sample has 100% saturation. All porosities reported are therefore assumed to be low. Despite this, the overall porosity map appears to accurately depict the porosity trends and relative values.

RESULTS

Sediment Texture

The surface sediments (0-10 cm.) in the southern gulf indicate a large central area of sand grading into finer sediments to the northeast and west (Figure 3). The silt to the west is locally penetrated by tongues of finer and coarser clastics. The median diameters of surface sediments show the central sand area divided into three areas separated by silt (Figure 4). Two sand tongues extend southeast into deeper water, and a third extends southwest from Hai-Nan Tao. A tongue of clay curves south from Hai-Nan Tao and another extends east and north of the Isle du Tigre (17°10'N, 107°20'E). A minor area of clay lies further to the north.

The surface sediments to the south and southwest of Hai-Nan Tao are very poorly sorted (Trask value $>$ 5, Figure 5). Locally the sorting is very poor to the west and north of the area surveyed. The sediments are better sorted ($<$ 3) in the deeper waters near the center and to the southeast. A narrow tongue of fair to poor sorting parallels the axis of the basin.

The sediments from 10-20 cm. show a partial restriction of the sand in the center of the area (Figure 6). Clay has become dominant along the western edge of the survey area. Small patches of sand remain to the south and west.

From 20-30 cm. depth, the sand in the center is further restricted (Figure 7). Silt and clay are now present over most of the area. Scattered patches of sand remain but sample spacing prevents a more accurate mapping. Most of the cores longer than 30 cm. penetrated various clay beds.

Total sand thickness of the upper 50 cm. thins from northwest to southeast reflecting the NW-SE trend of the gulf (Figure 8). The major sand deposits lie within the trough with local build-ups to the west and northeast.

Calcium Carbonate

Calcium carbonate distribution is shown in Figures 9, 10, and 11. The higher concentrations ($>$ 25%) may reflect the *in situ* growth of bottom organisms. Gastropods, pelecypods, and calcareous algae account for most of the carbonate; foraminifera, pteropods, and corals represent the remainder. Some deeper water sands contain a significant amount of reworked shallow water shells. The carbonate content at the 10-20 cm. depth (Figure 10) indicates a possible shoaling at an earlier time with the development of an optimum growth area along a NE-SW line (Figure 10). A still earlier shoreward shoaling is indicated by the 20-30 cm. carbonate values (Figure 11).

Engineering Properties

Phleger cores are not suited for use in engineering properties analyses due to the small diameter, sample disturbance, and perhaps most important, the water loss.

Examination and tests of some of the cores disclosed that the plastic wrappings on the liners apparently reduced the water loss. Since no engineering data exists in this area, engineering properties were attempted on some cores.

Cohesion increases from the shallow flanks into the deeper, sandy trough (Figures 12 and 13). It also increases with depth on the flanks but apparently decreases in the basin. This is probably due to the silts and clays underlying the sands in the basin.

The cohesion is affected by several factors. Evaporation of water from clays and drainage and evaporation from sands will increase the apparent strength and cohesion. Disturbance of the sample by coring, handling, shipping, and extrusion in the laboratory will reduce the cohesion. To some extent these factors compensate each other. In the cores studied the cohesion values are probably high due to water loss. Figures 12 and 13 therefore reflect relative, rather than true, values.

The wet unit weight of surface sediments increases into the silty and argillaceous sands of the basin (Figure 14). The highest unit weights lie along the axis of the trough. Again the contours follow the axis of the trough with local variations due to multiple sediment sources.

All of the engineering parameters studied are greatly affected by the morphology of the gulf and the varying sources of sediment. The sand fill has higher strengths and lower porosities than would normally be expected in deeper waters. The sediments of the shallow current-swept flanks of Hai-Nan Tao and the longshore areas of Vietnam are affected by the distance from sediment source and current velocity variations. In these shallow waters, competent sands are separated by incompetent clays and silts.

SEDIMENTATION

The sediments studied have three major sources. These are: (1) nearby minor river deltas to the west and southwest, (2) the Ch'ang Chiang Ho delta on Hai-Nan Tao to the northeast, and (3) the Hong (Red) River delta to the north (Figure 1).

In the first group, nearby deltas of the Chaing, Dia Giang, Ben and Cam Lo Rivers supply clays and silts and a minor amount of sand to the western edge of the area (Bell, 1966). Shallow water around Isle du Tigre masks part of the basin from the strong nearshore currents and produces a large area of clay as shown in Figure 3.

The next major source of sediment is the Ch'ang Chiang Ho delta on western Hai-Nan Tao. Charts indicate that the longshore currents winnow the deltaic sands and deposit them as offshore bars along the southwest flanks of the island. Some of these sands are swept southwest into deeper waters. South of Hai-Nan Tao, reduced currents and increased distance from the source favors clay deposition.

The third and possibly largest source of sand is the Hong (Red) River in North Vietnam. Sediments that are not trapped in the deltaic build-up move into the gulf and are dispersed by longshore currents. Turbidity currents moving down the axis of the gulf could account for the large amounts of sand in the center of the area studied.

The sorting coefficient of the upper 10 cm. generally indicates the various sediment sources (Figure 5). The line of better sorting (< 3) to the southeast roughly follows the deepening of the gulf into the South China Sea. This may be the result of turbidity currents sorting and depositing the coarser fractions in a downslope direction.

The sorting coefficients of the deeper sediments follow similar patterns. The sediments between 10 and 30 cm. (Figures 6 and 7) were influenced by the same sources as the present surface. A NE-SW trend of the sand-silt contact is probably due to turbidity current sorting.

OLDER BEDS

Several cores penetrated a light blue clay that is significantly different in color and texture from the overlying clays. This clay may be Pleistocene in age. Other cores reached a reddish brown, silty, varved, stiff clay of Pleistocene (?) age. The contacts between the

upper beds and these clays are unconformable. Occasionally 1-2 cm. of sand is present along the contact. One core (E27) contained inclusions of reddish brown clay in the upper beds. These inclusions are identical with the reddish brown clay horizon, and may be "clay balls" from nearby outcrops. Several cores contained reddish brown clay in worm tubes and burrows. None of the cores penetrated both the blue and reddish brown clays.

RECOMMENDATIONS

This study was greatly hampered by the small diameter and short length of the cores available. Additional studies in the area should be made with larger cores. Additional coring is also needed to trace the sands further to the north toward the major sources and into shallow waters to the west in an effort to tie in with recent coastal studies.

NOTE ON DATA ANALYSIS : Data sediment characteristics are presented in NAVOCEANO Laboratory Item No. 370, "A Summary of Engineering Properties, Sediment Size and Composition Analysis of Cores and Bottom Samples from the Southern Gulf of Tonkin, 1966".

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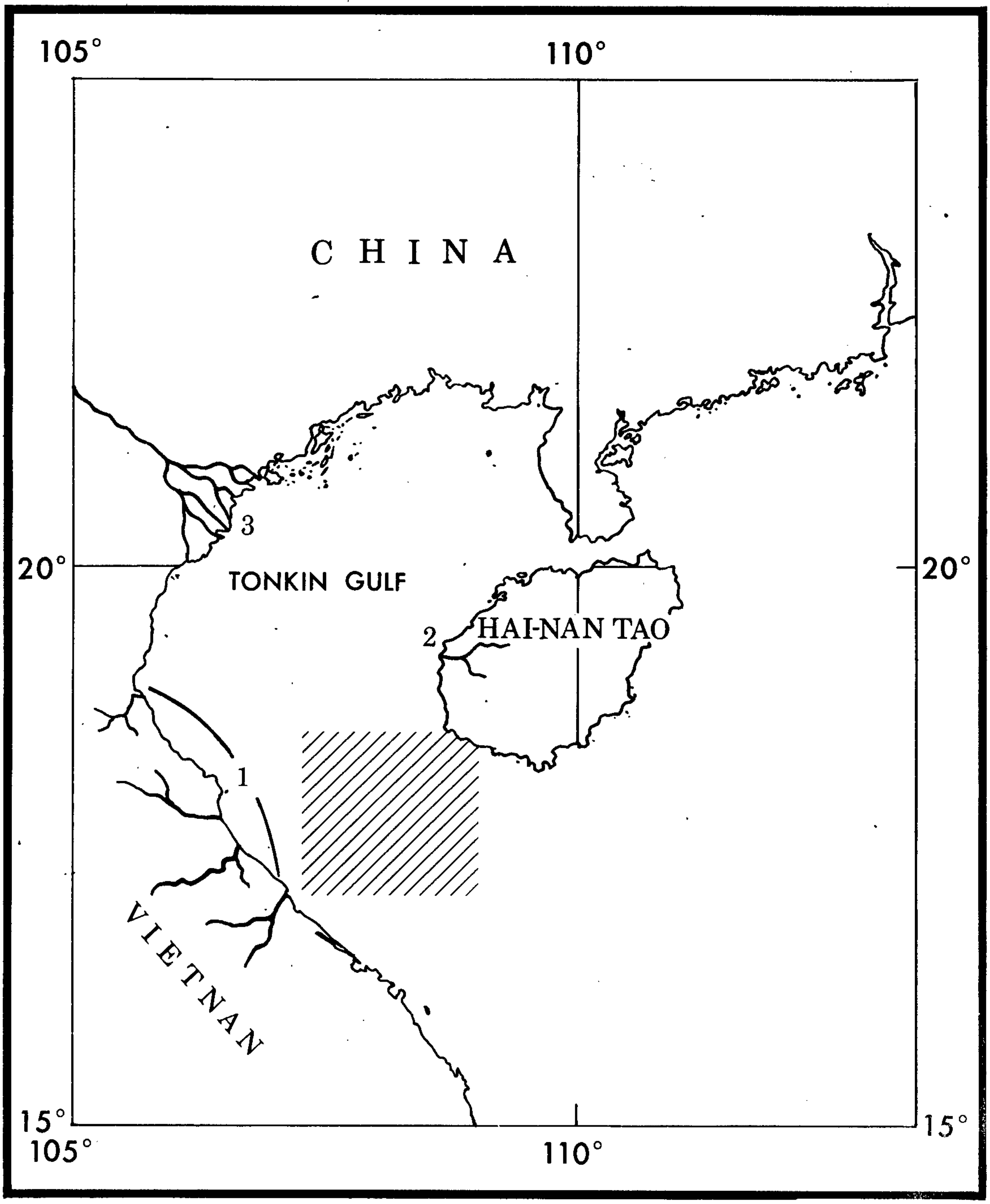
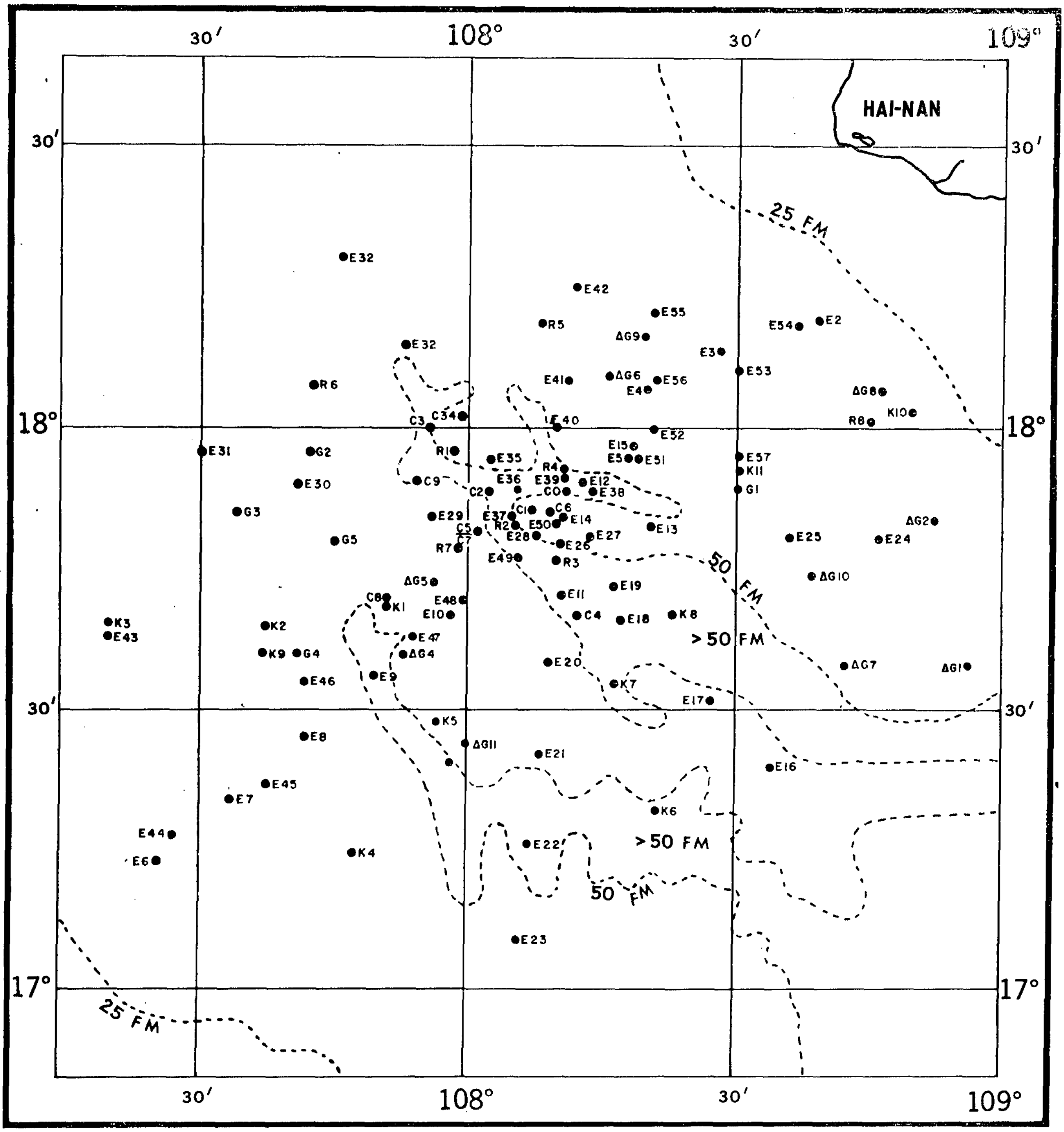


FIGURE 1. LOCATION OF SURVEY AREA



FIGURE– 2 LOCATION OF CORES.

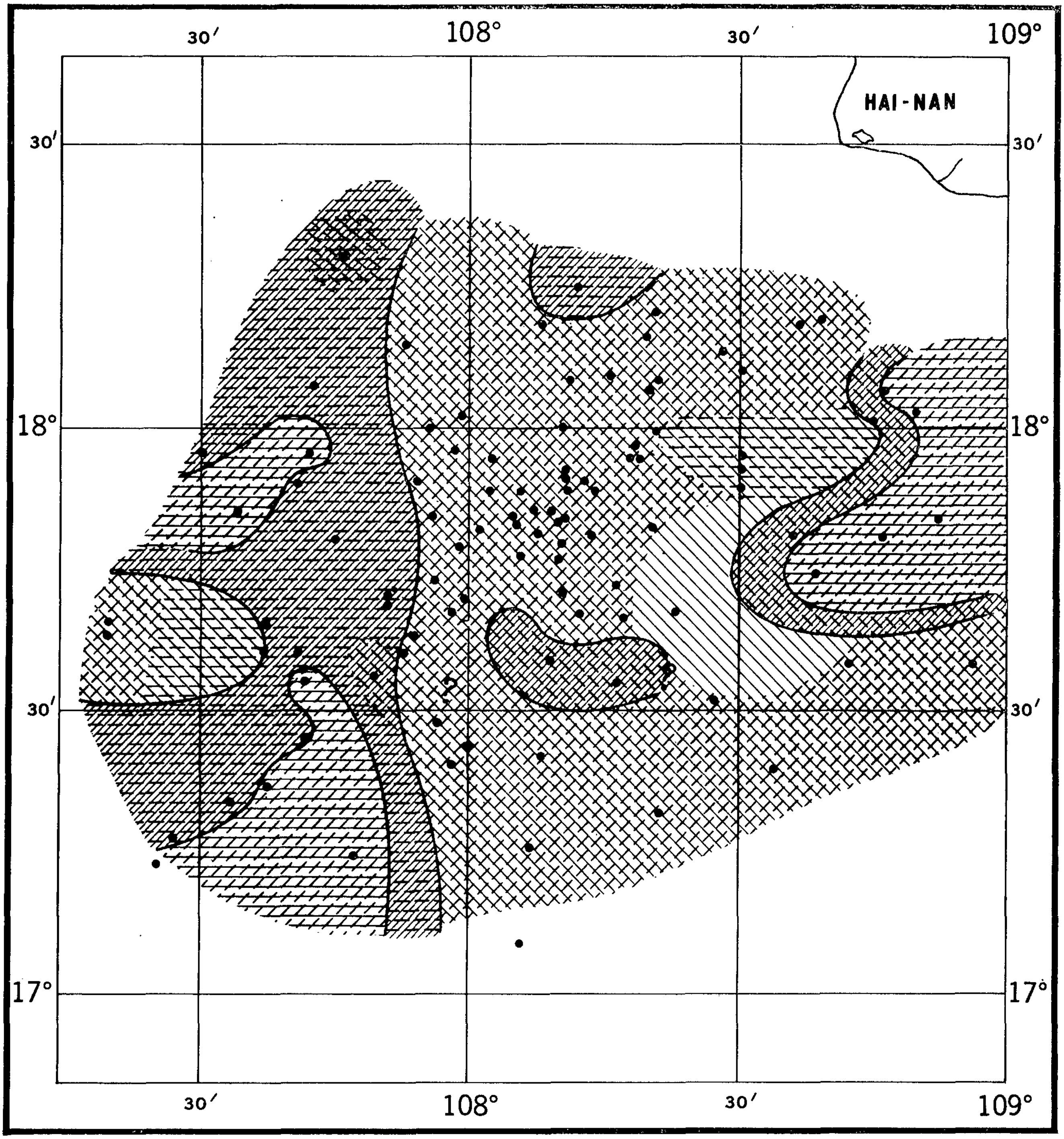
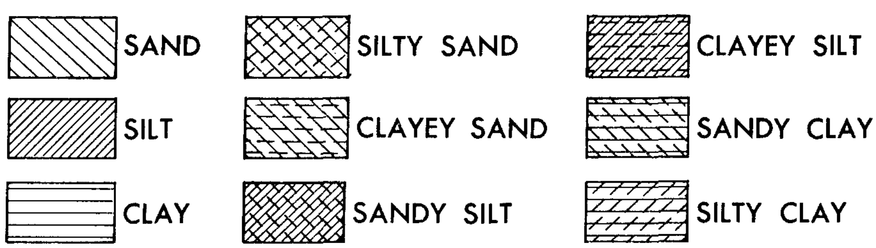


FIGURE- 3 SEDIMENT TYPE 0—10 Cm. DEPTH.



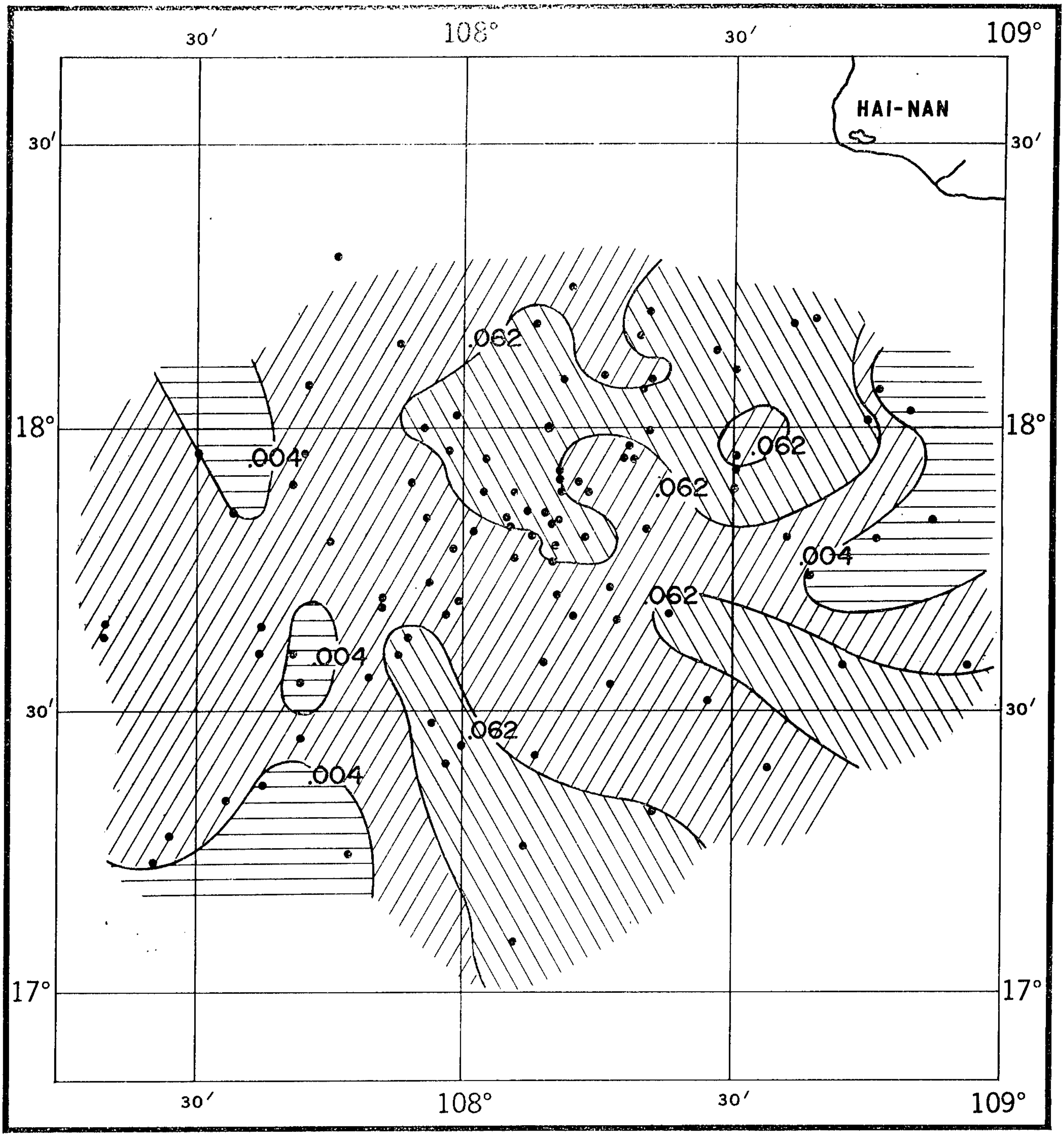
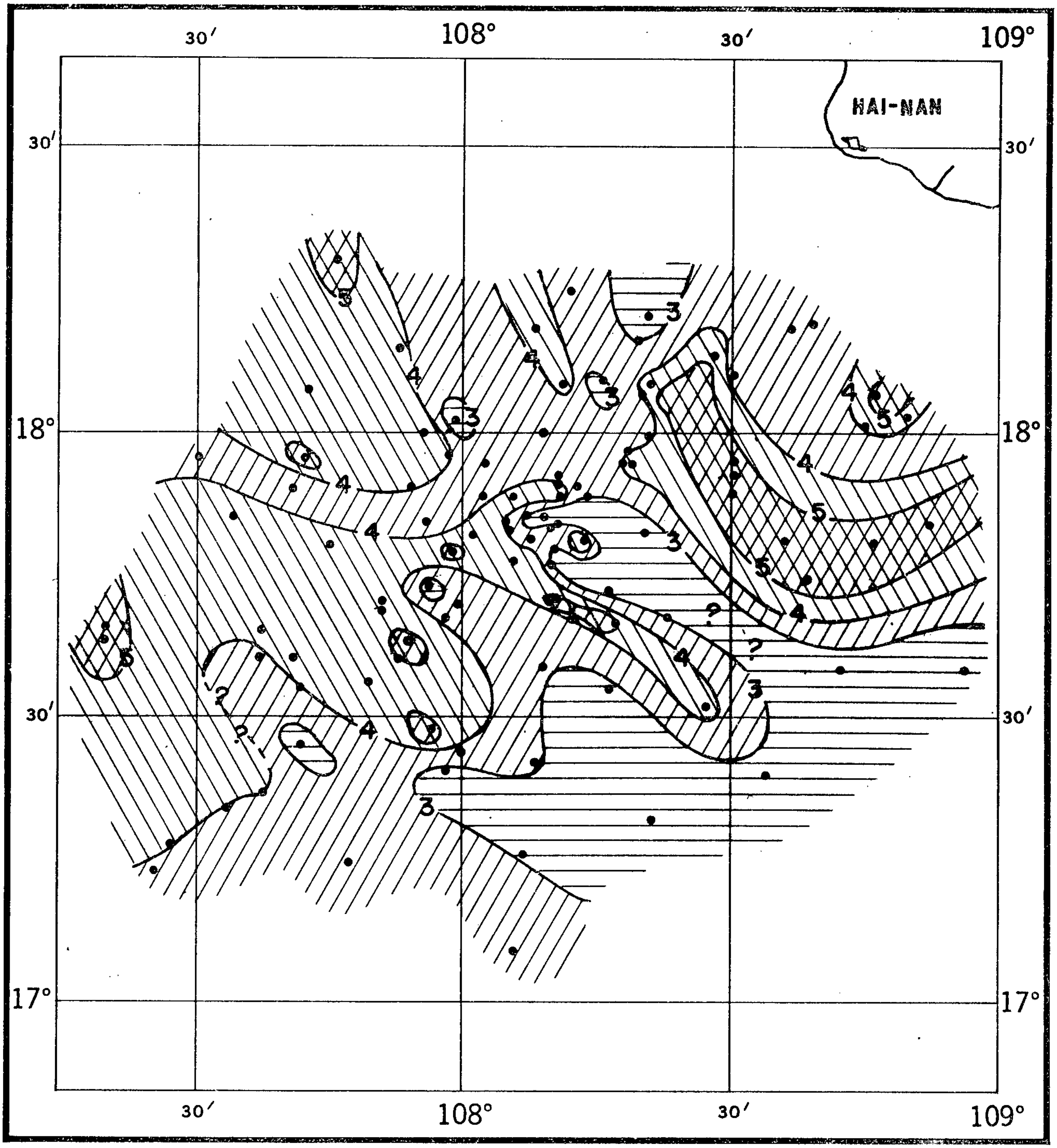


FIGURE- 4 MEDIUM DIAMETER mm. 0—10 Cm. DEPTH.

>.062 mm. SAND

>.004 mm. SILT

<.004 mm. CLAY



FIGURE– 5 SORTING COEFFICIENT 0—10 Cm. DEPTH.

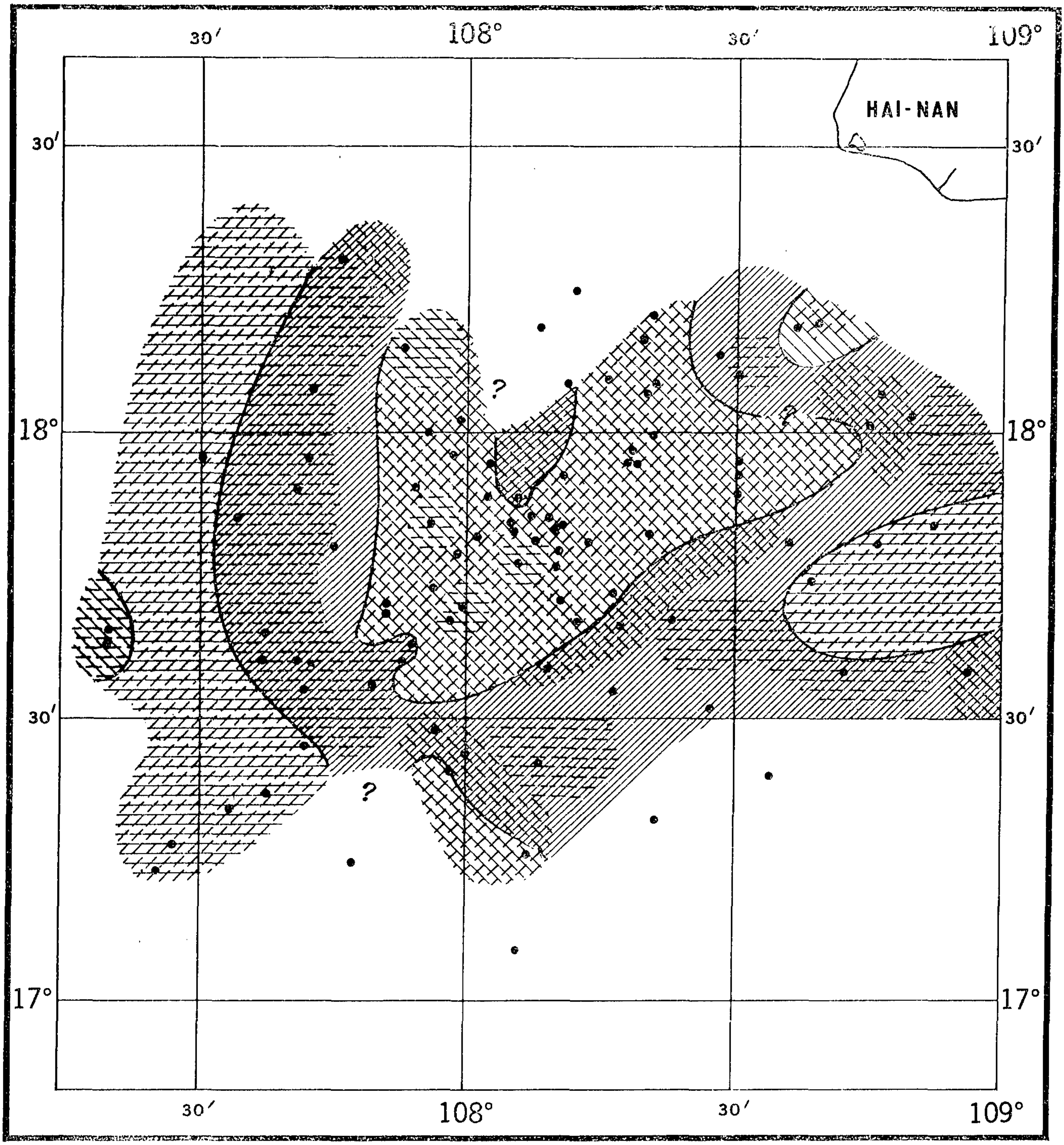
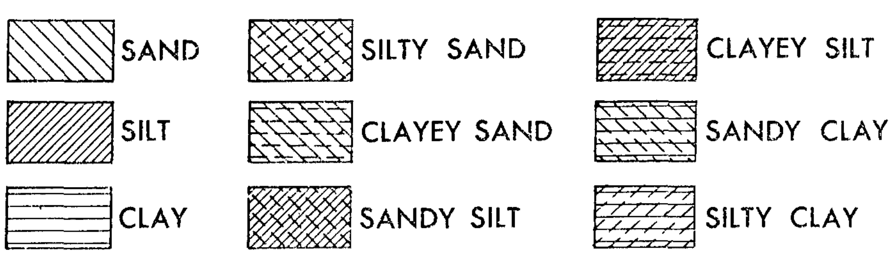
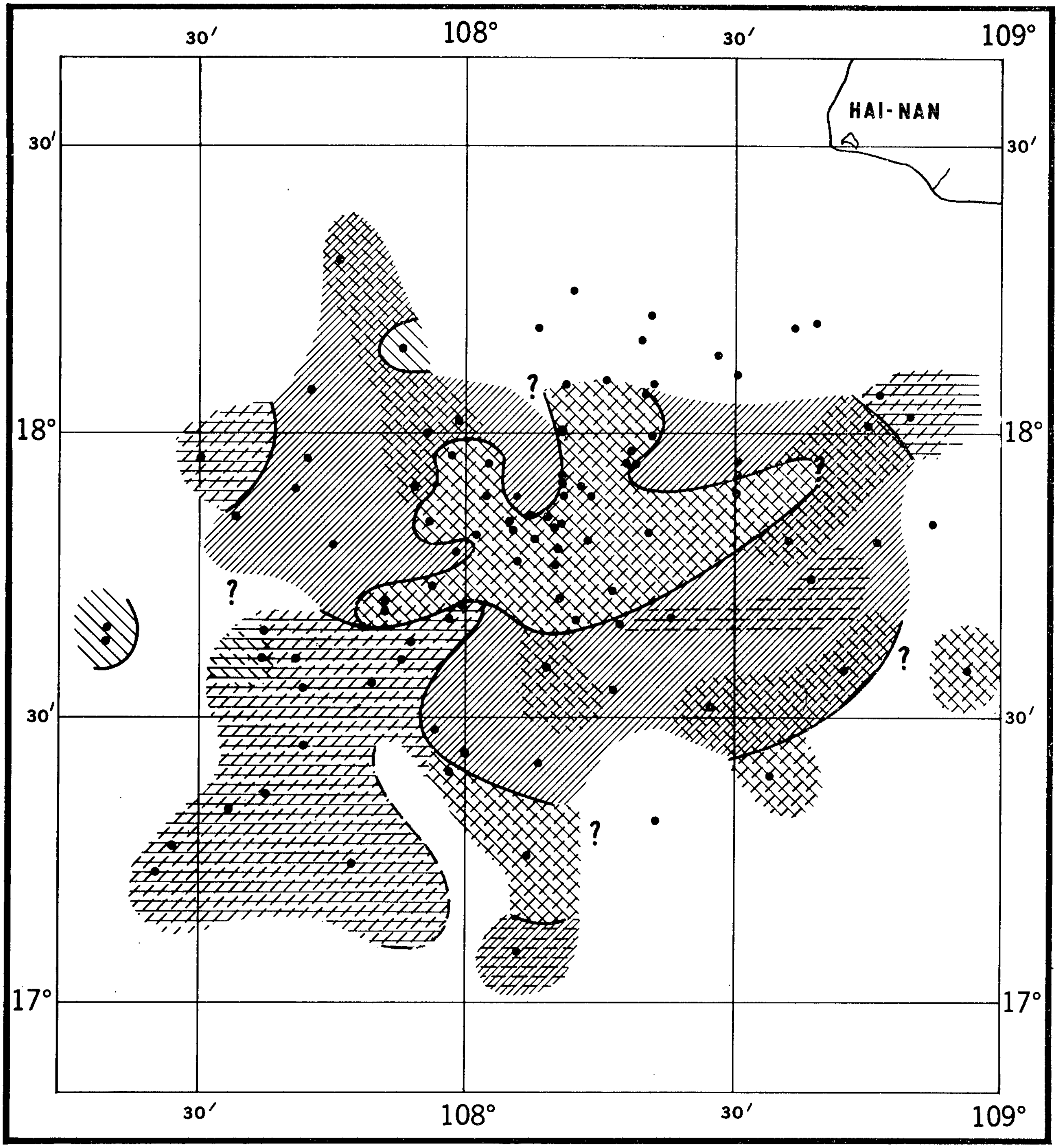
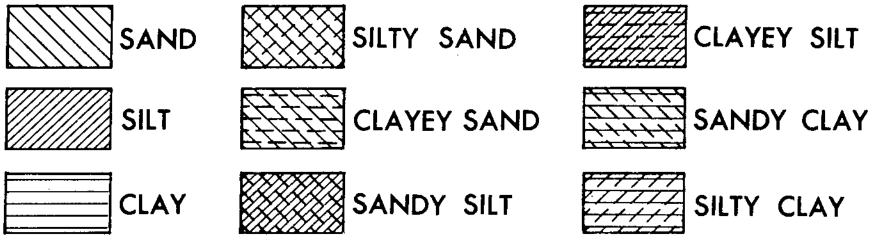


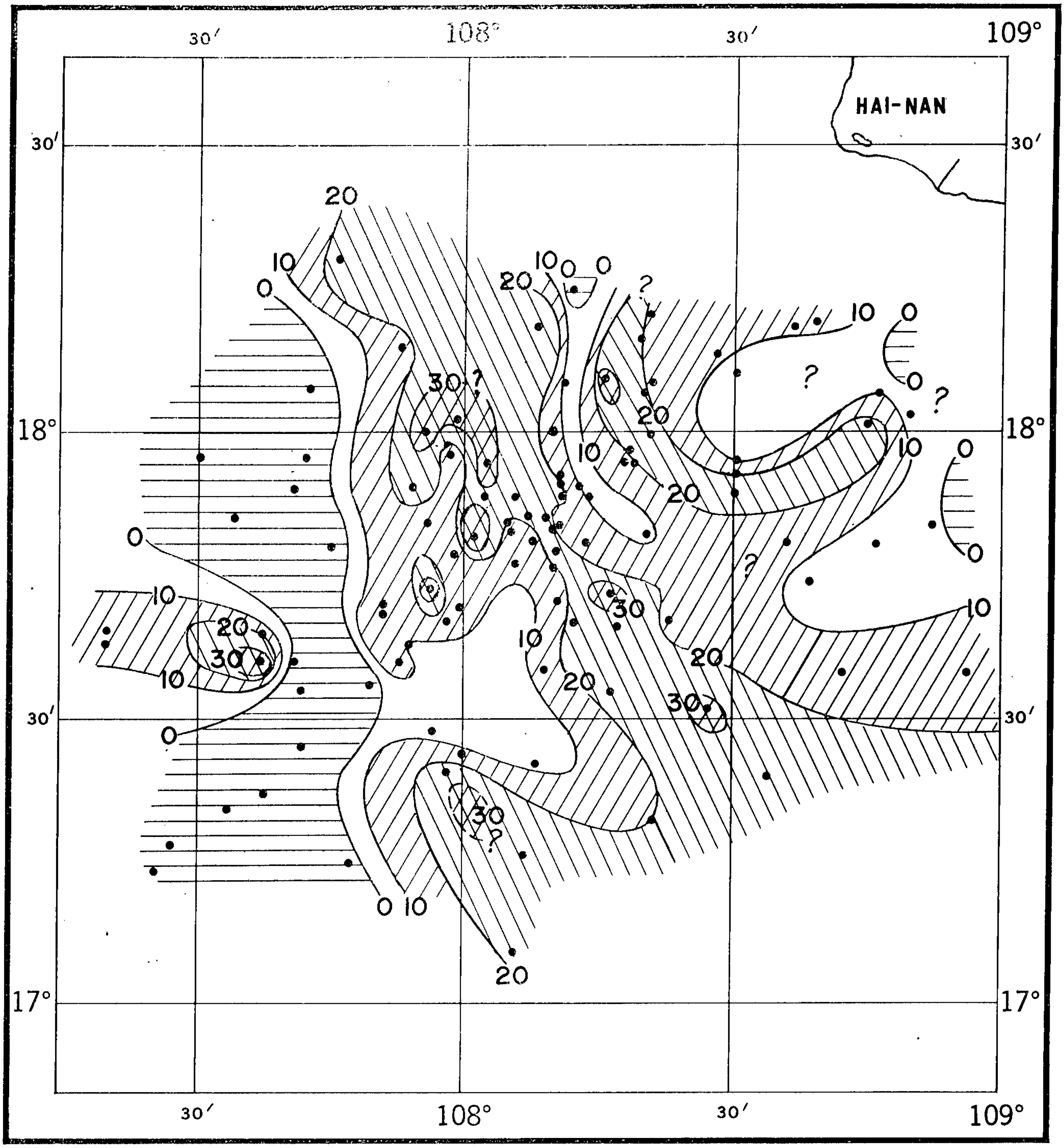
FIGURE- 6 SEDIMENT TYPE 10—20 Cm. DEPTH.



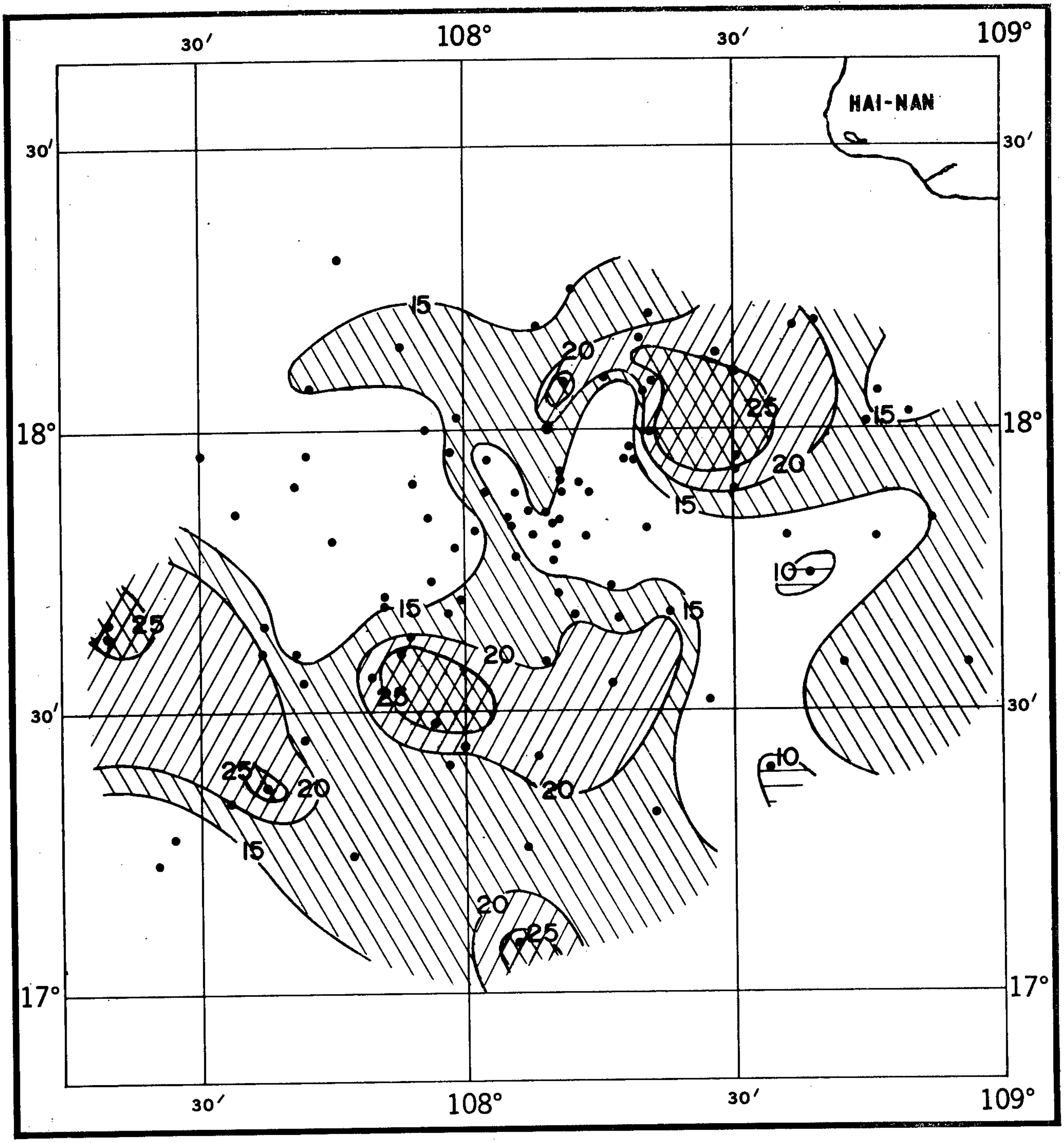


FIGURE– 7 SEDIMENT TYPE 20—30 Cm. DEPTH

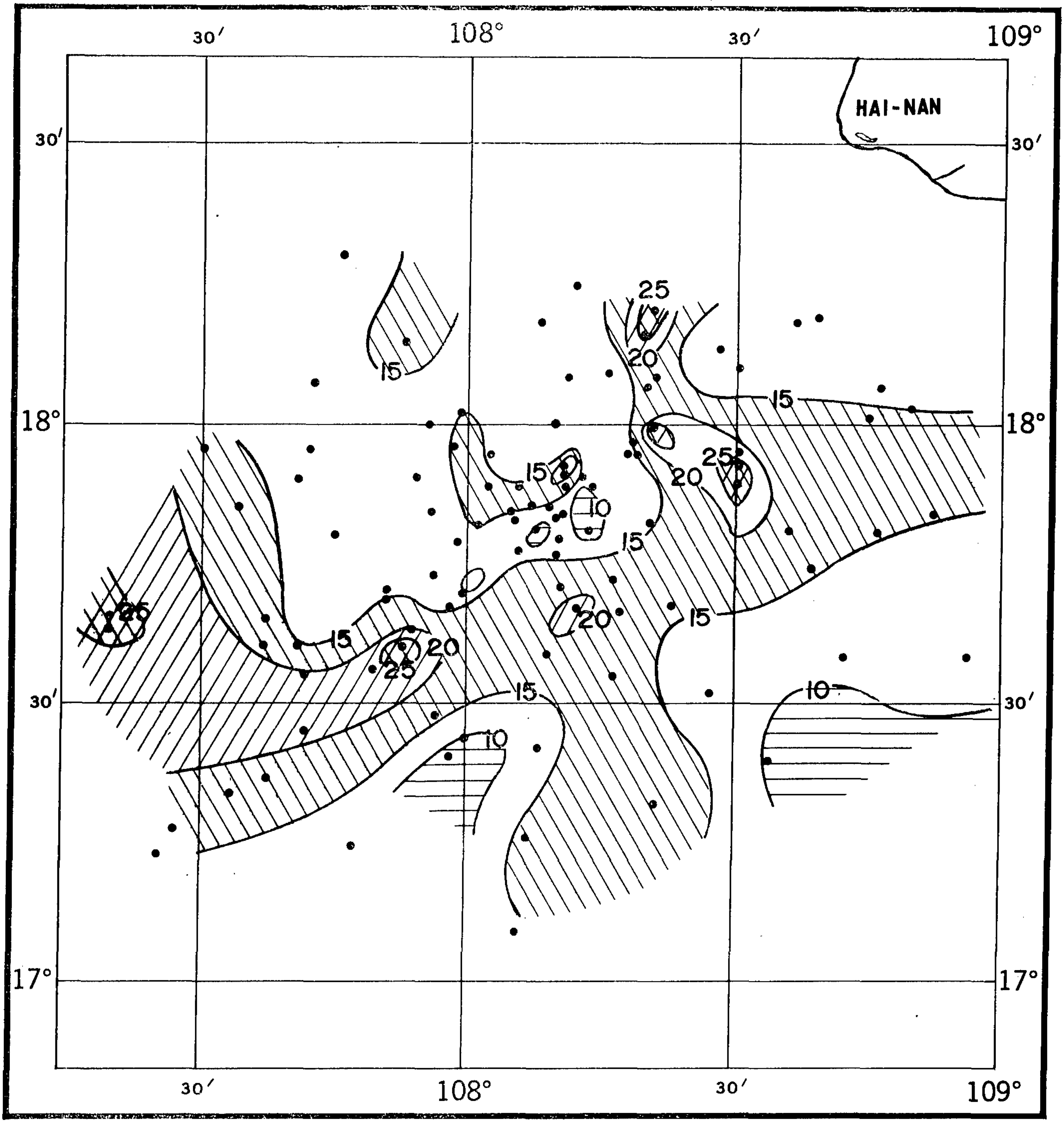




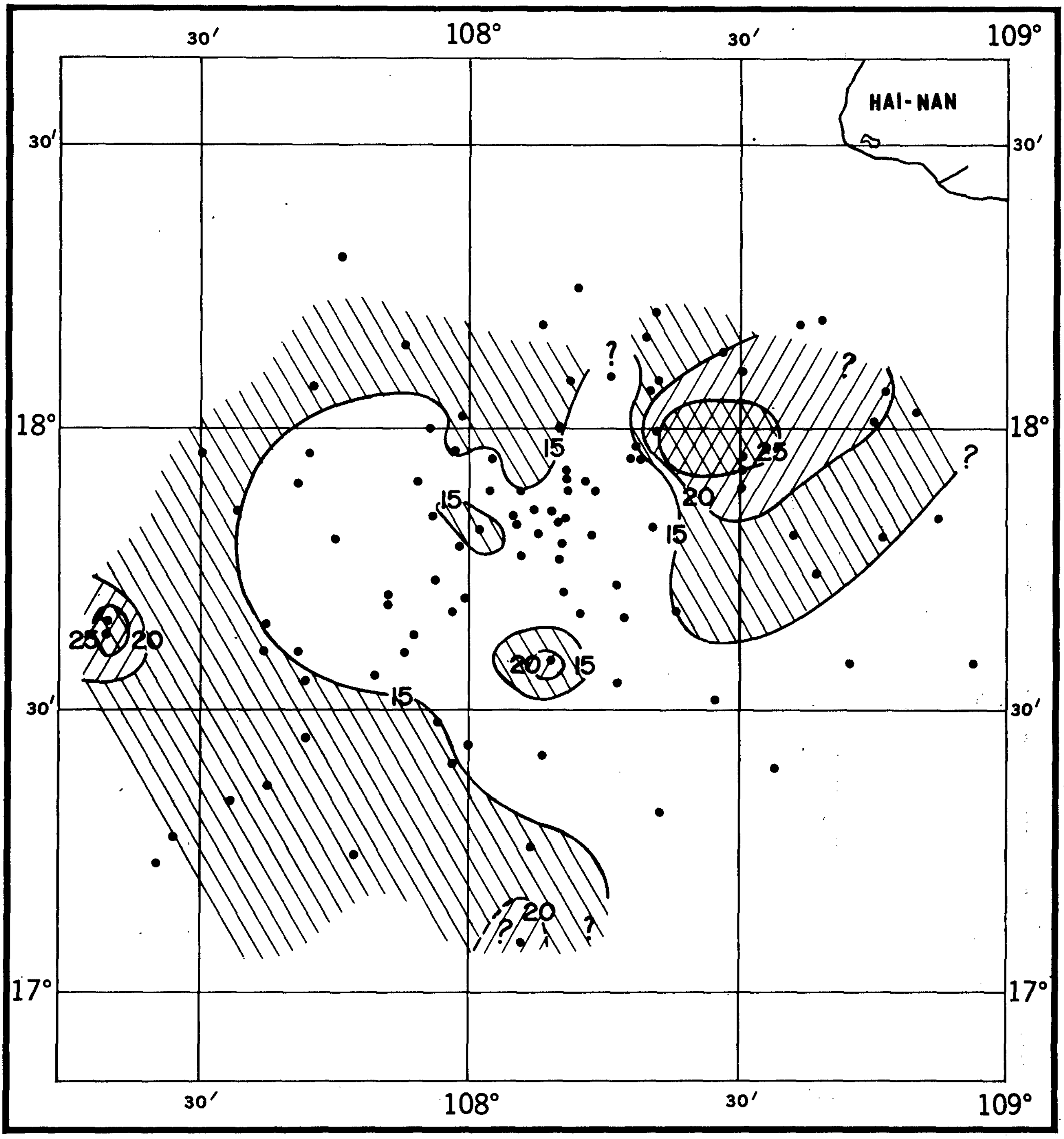
FIGURE– 8 SAND THICKNESS OF UPPER 50 Cm. DEPTH CONTOUR INTERVAL 10 Cm.



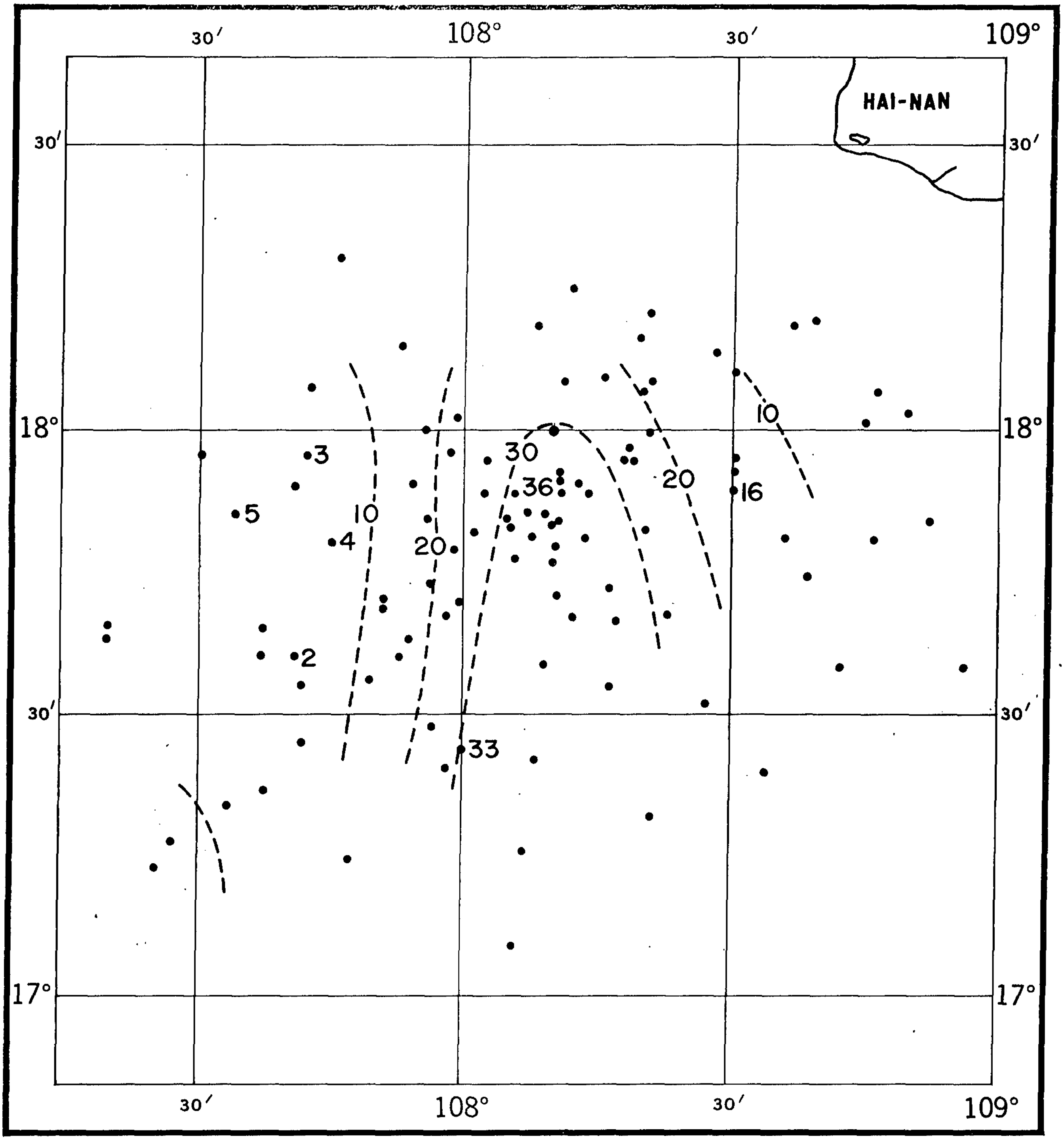
FIGURE– 9 CALCIUM CARBONATE PERCENTAGE 0—10 Cm. DEPTH.



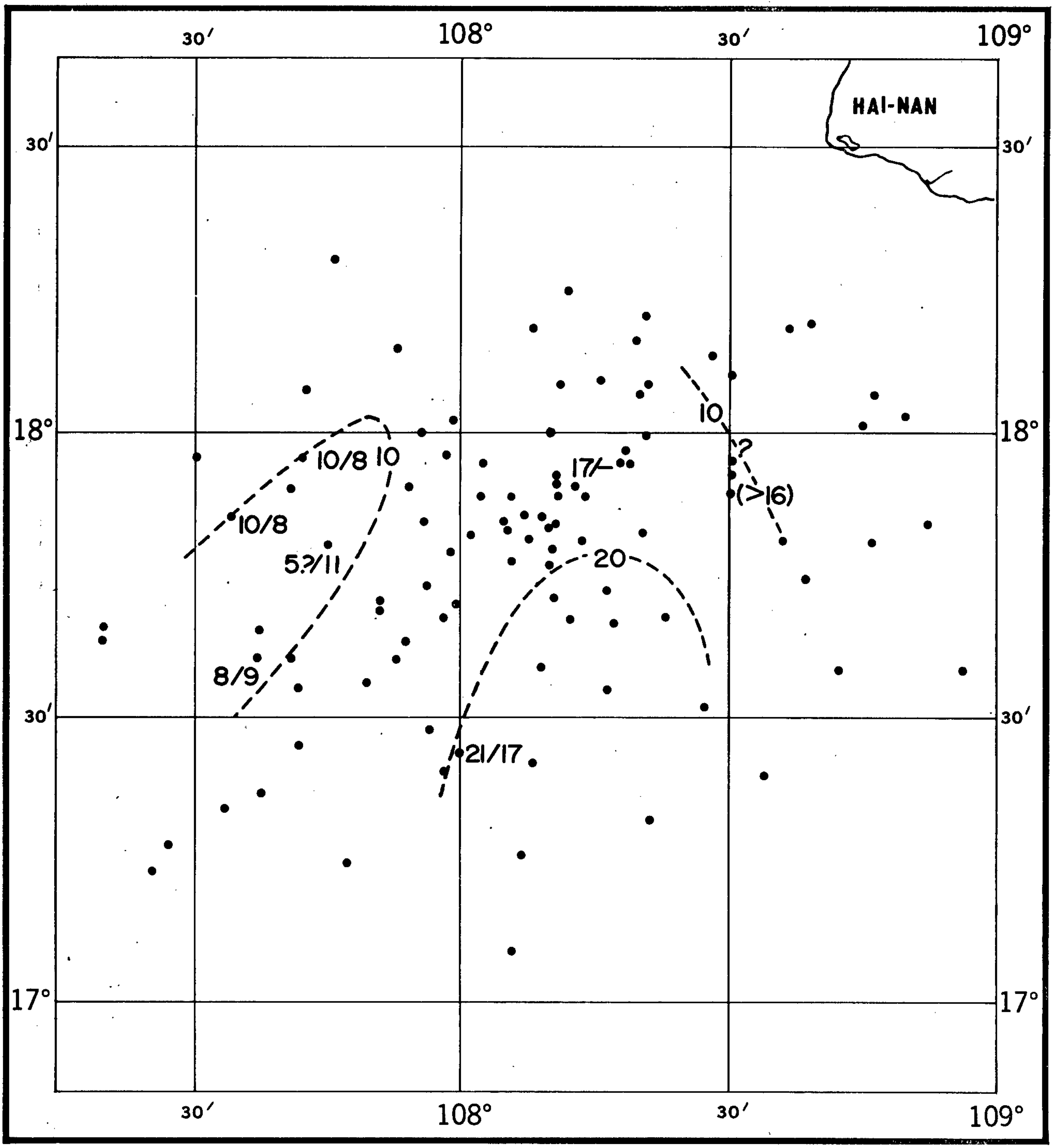
FIGURE– 10 CALCIUM CARBONATE PERCENTAGE 10—20 Cm. DEPTH.



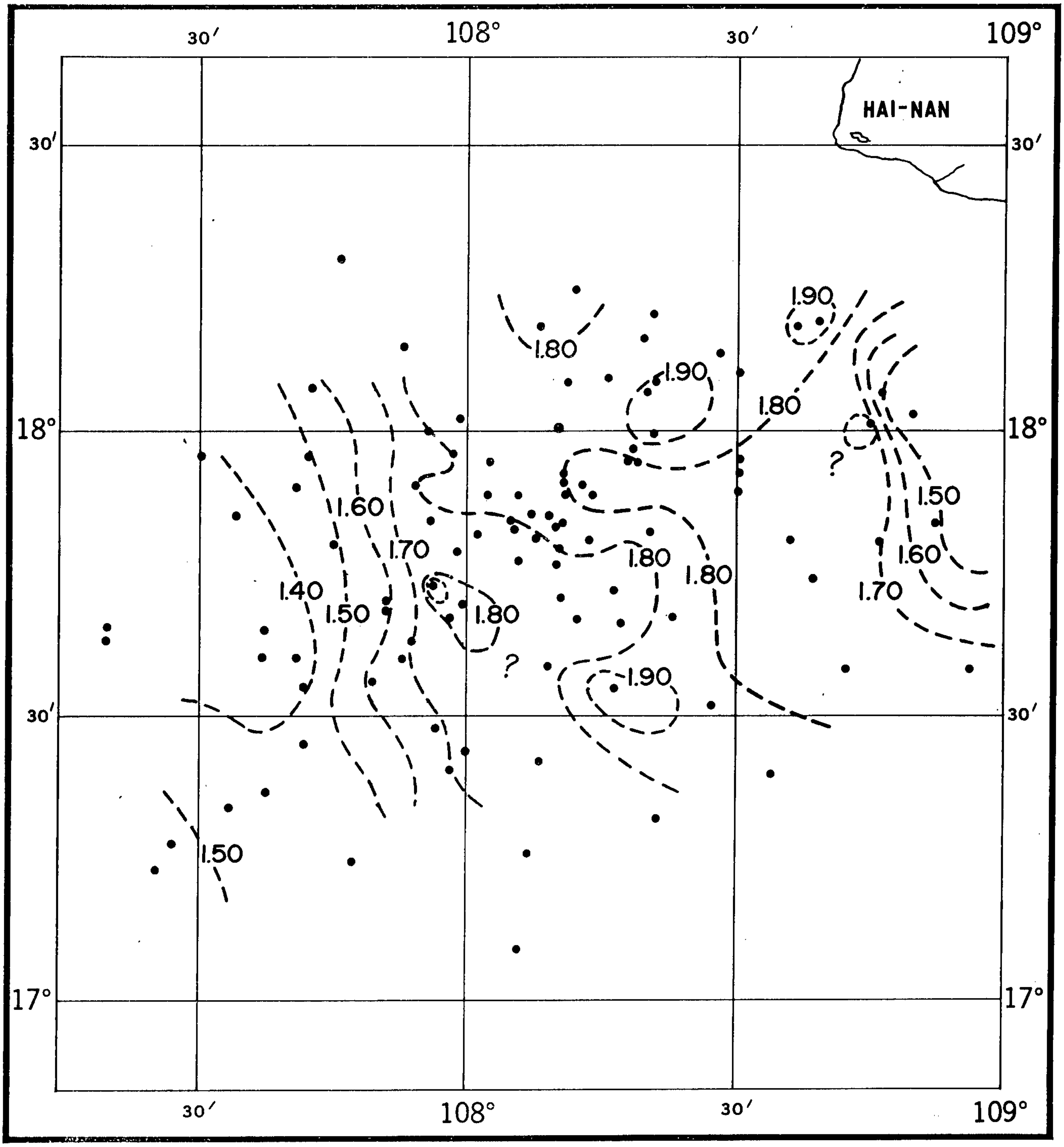
FIGURE– 11 CALCIUM CARBONATE PERCENTAGE 20—30 Cm. DEPTH.



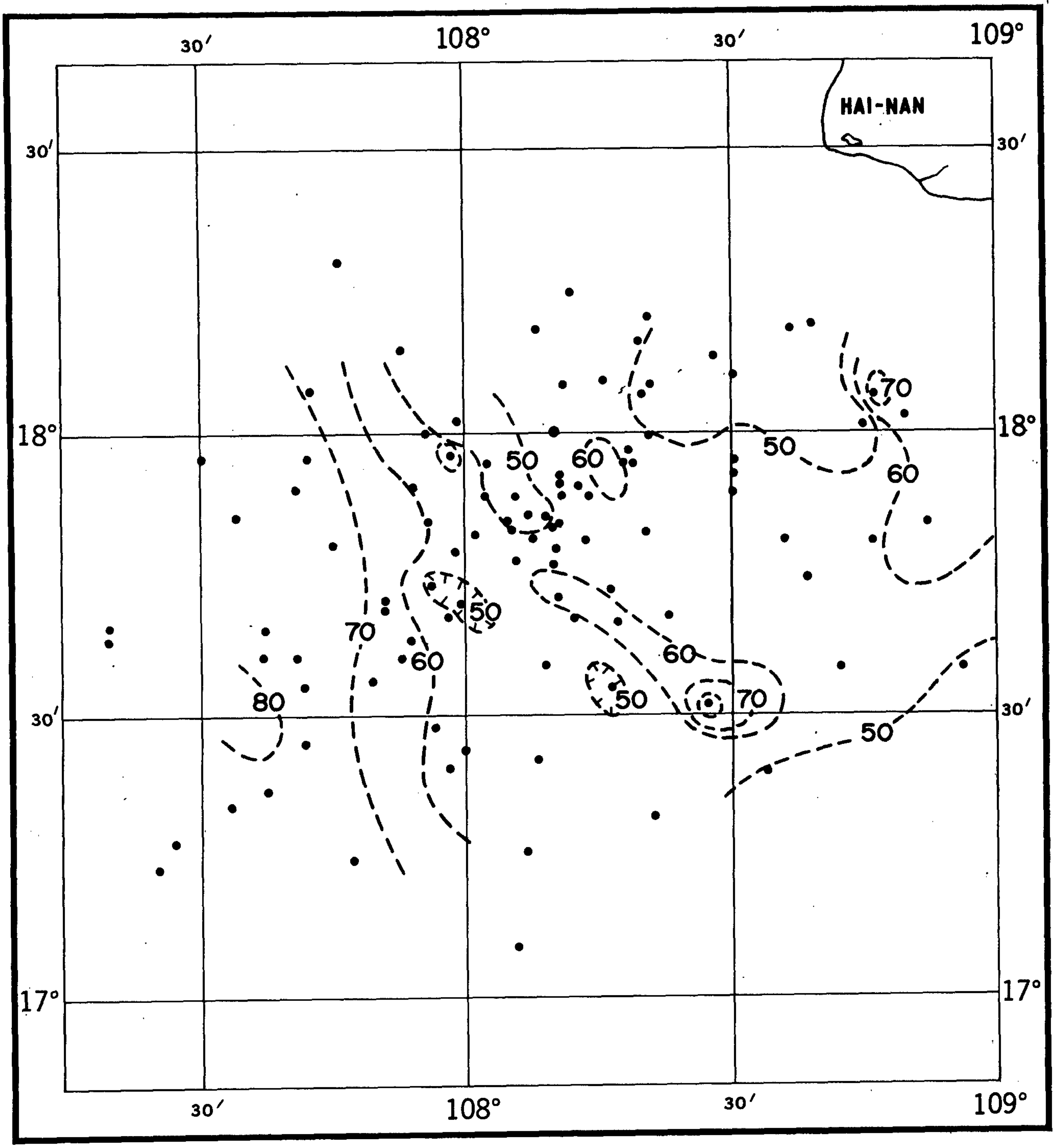
FIGURE– 12 COHESION Gm./Sq. Cm. 0—10 Cm. DEPTH.



FIGURE–13 COHESION Gm./Sq. Cm. $\frac{20\ \text{Cm.}}{40\ \text{Cm.}}$ DEPTH.



FIGURE– 14 WET UNIT WEIGHT Gm./Cu.Cm. 0—10 Cm. DEPTH.



FIGURE–15 POROSITY PERCENTAGE (ESTIMATED) 0–10 Cm. DEPTH.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Geology						
Sedimentation						
Marine Geology						
Clay						
Sand						
Silt						
Gulf of Tonkin						
Ocean Bottom Sampling						